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RESEARCH ARTICLE

Shifts in soil bacterial communities induced by the controlled-release fertilizer coatings

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Abstract

Coated controlled-release fertilizers (CRFs) have been widely applied in agriculture due to their increased efficiency. However, the widespread and a lot of coated CRFs application may leave undesired coating residues in the soil due to their slow degradation. Limited information is available on the effects of substantial residual coatings on the soil bacterial community. By adding 0, 5, 10, 20, and 50 times quantities of residual coating from conventional application amount of resin and water-soluble coated CRFs, we studied the responses of soil properties and bacterial community composition to these two residual coatings in black soil. The results showed that the resin and water-soluble coatings did not essentially alter the properties of black soil or cause dramatic changes to bacterial diversity within the test concentration range. The residual resin and water-soluble coatings also did not distinctly alter the relative abundance of the top ten bacteria at phylum level. Heatmap results suggested that the treatments were basically clustered into two groups by concentration rather than types of coating material. Pearson correlation analysis showed that the Simpson's diversity index of the bacterial community was significantly correlated with microbial biomass carbon (MBC, r=0.394, P<0.05), and the richness index abundance-based coverage estimator (ACE) of the bacterial community was significantly correlated with microbial biomass nitrogen (MBN, r=0.407, P<0.05). Overall, results of this study suggested that substantial residual resin and water-soluble coatings with 0–50 times quantities of residual coating from conventional application amount of coated CRFs did not generate obviously negative impacts on the bacterial community in black soil.

Keywords: soil bacterial community, controlled-release fertilizer, residual coatings, 454 pyrosequencing

1. Introduction

Nitrogen fertilizing is one of the major limiting factors that affect crop yield. However, about one-third to half of applied nitrogen is lost to groundwater and atmosphere due to leaching and volatilization, respectively (Lægreid *et al.* 1999; Prasad 2013). Therefore, there is a worldwide demand for the development of more efficient nitrogen fertilizers. Slow-/controlled-release fertilizers (SRFs/CRFs) are ideal and popular fertilizers to improve nitrogen use efficiency

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and reduce environmental hazards owing to their following characteristics: a) One single application supplies the necessary amount of nutrients for plant growth; b) higher crop output can be achieved with lower fertilizer input; c) they cause minimum adverse effects on the soil, water, and atmosphere (Shoji and Gandeza 1992).

Numerous studies have indicated that coated CRFs have potential benefits in enhancing nitrogen use efficiency and reducing nitrogen leaching. The use of polymer-coated urea (PCU), instead of conventional soluble urea, resulted in improved yields and nitrogen use efficiency in crops, including potato (Zvomuya and Rosen 2001; Hutchinson *et al.* 2002; Zvomuya *et al.* 2003; Kang and Han 2005; Pack *et al.* 2006; Wilson *et al.* 2009), rice (Fashola *et al.* 2002), and onion (Drost *et al.* 2002). In addition, a reduction in nitrate leaching losses and nitrogen oxide emission had also been achieved using PCU (Hyatt *et al.* 2010). For instance, PCU application in northeastern Missouri resulted in a lower nitrate leaching as compared with the conventional urea application at a depth of 45 cm (Motavalli *et al.* 2006). Similarly, Zvomuya *et al.* (2003) also found that nitrate leaching during the growing season was 34 to 49% lower following PCU application, when compared with urea application, at the recommended rate of 280 kg N ha^{-1}.

Due to the advantages of CRFs, they have been recognized as one of the most promising fertilizers that can be applied to agricultural systems. Therefore, many studies have been devoted to finding new coating materials that are better in controlling the release of nutrients and are environmental friendly, such as microparticles (Roy *et al.* 2014). However, the potential hazards of accumulating residual coatings from application of CRFs have been ignored for years, a few researchers have highlighted this issue (Shoji and Kanno 1994; Trenkel 1997; Shaviv 2001; Subbarao *et al.* 2006). For example, Shoji and Kanno (1994) indicated that PCU may leave undesired residues of plastic in the fields (up to 50 kg ha^{-1} yr^{-1}), which may perturb the soil microenvironment, resulting in a microbial composition change and influencing the biogeochemical cycles. Therefore, it is necessary to identify the microbial compositions of soil containing undesired coating materials.

To address if substantial residual coatings affect the soil properties and bacterial community, we conducted the physicochemical analysis for the soil samples after residual coating application and further studied the microbial composition using pyrosequencing approach.

2. Materials and methods

2.1. Experimental design

Soil collections were carried out on private land and we confirm that the owner of the land gave permission for us to conduct the study on this site.

The black soil for pot experiments was collected from a farmland located in Gongzhuling, Jilin Province, China (125°19´E, 42°52´N). The basic properties of the collected soil were as follows: pH, 6.14; organic matter, 16.2 g kg^{-1}; total nitrogen, 1.37 g kg^{-1}; total phosphorus, 0.59 g kg^{-1}; total potassium, 18.77 g kg^{-1}; NaOH-hydrolyzed nitrogen, 139.31 mg kg^{-1}; available phosphorus, 28.19 mg kg^{-1}; and available potassium, 167.73 mg kg^{-1}.

Resin and water-soluble coatings, which are the two kinds of typical coating materials of CRFs in China, were applied in this study. The resin coating added in experiment is a type of thermoplastic material made of polyurethane which contains 46% of solids, was obtained from a urea fertilizer coated with resin (coating accounting for 5% of the weight of the fertilizer, Shandong Kingenta Co., Ltd., China). The urea fertilizer was smashed to isolate the resin coating and remove the encapsulated urea using the following five steps: a) The controlled-release urea fertilizer was smashed using a universal pulverizer; b) the encapsulated urea was soaked out with tap water for 24 h after smashing; c) the resin coating material was filtered and washed with deionized water five to seven times; d) the resin was dried in an electro-thermostatic blast oven (60°C for 10 h); and e) the resin coating material was isolated by passing through a 2-mm sieve. Water-soluble acrylic ester polymer blend provided by Shandong Kingenta Co., Ltd., was selected as the water-soluble coating added in tested soil directly, which was viscous and contained 48% of solids.

Based on the application rate of nitrogen fertilizer applied conventionally by local farmers (195 kg N ha^{-1}), the amount of the resin (0.206 g) and water-soluble (0.118 g) residual coatings in 10 kg soil per pot (250 mm×300 mm) was calculated. And then 5, 10, 20 and 50 times of the amounts of two coatings were also calculated and further added into pots. Both coatings had four concentrations, combined with a control treatment with no coatings, therefore resulting in nine treatments in total. These treatments with residual quantities of the coating material were designed as follows: (1) no coating (control), (2) 5 times quantities of residual resin coating (R5, 0.103 g kg^{-1}), (3) 10 times quantities of residual resin coating (R10, 0.206 g kg^{-1}), (4) 20 times quantities of residual resin coating (R20, 0.412 g kg^{-1}), (5) 50 times quantities of residual resin coating (R50, 1.030 g kg^{-1}), (6) 5 times quantities of residual water-soluble coating (W5, 0.059 g kg^{-1}), (7) 10 times quantities of residual water-soluble coating (W10, 0.118 g kg^{-1}), (8) 20 times quantities of residual water-soluble coating (W20, 0.236 g kg^{-1}), and (9) 50 times quantities of residual water-soluble coating (W50, 0.590 g kg^{-1}). To ensure homogeneous mixing, 10 kg soil was divided into 10 portions for all resin